NERRS Science Collaborative Progress Report for the Period 3/1/2012 through 8/30/2012

Project Title: A collaborative approach to address larval supplies and settlement as critical early life-history issues during restoration of native Olympia oysters (*Ostrea lurida*) in Coos Bay and the South Slough estuary

Principal Investigator(s): Dr. Steven Rumrill

Project start date: Nov 2010

Report compiled by: Steven Rumrill / John Bragg

Contributing team members and their role in the project:

Integration Leader: Frank Burris, Extension Watershed Educator
Oregon State University Extension Service
Gold Beach, OR
Role in project: Facilitation of interactions between the stakeholders (Olympia Oyster Restoration Advisory Committee) and project team members. Mr. Burris has expertise with community stakeholder discussions in rural environments, and will provide for integration and leadership through the joint fact-finding / structured decision-making process.

Co-Principal Investigators: Dr. Craig Young, Professor of Biology
University of Oregon / Oregon Institute of Marine Biology
Charleston, OR
Role in project: Director of OIMB and collaborating project scientist with particular expertise in the reproductive biology and larval ecology of marine and estuarine invertebrates. Dr. Young will serve as the primary graduate thesis advisor for one graduate student (module 1 / reproduction and reproductive output) supported by the project.

Dr. Alan Shanks, Professor of Biology
University of Oregon / Oregon Institute of Marine Biology
Charleston, OR
Role in project: Collaborating project scientist with particular expertise in larval behavior, dispersal, and tidally-driven transport in estuaries. Dr. Shanks will serve as the primary graduate thesis advisor for one graduate student (module 2 / larval supplies and dispersal) supported by the project.

Dr. Richard Emlet, Professor of Biology
University of Oregon / Oregon Institute of Marine Biology
Charleston, OR
Role in project: Collaborating project scientist with particular expertise in larval development, hydromechanics, larval settlement, and metamorphosis. Dr. Emlet will serve as the

primary graduate thesis advisor for one graduate student (module 3 / larval settlement and metamorphosis) supported by the project.

Jamie Doyle, Marine Community Development Leader
Oregon Sea Grant Extension Program (Coos County)
Myrtle Point, OR
Role in project: Work with project team to develop a series of presentations, fact sheets, briefing materials to ensure that the stakeholders and scientists share a common level of understanding about the biology and ecology of Olympia oysters. Ms. Doyle has expertise with marine resource policy and management, community education, and outreach, and she will provide assistance to the Integration Leader with the SDM process.

John Bragg, Communications Leader
Coastal Training Program Coordinator
South Slough National Estuarine Research Reserve
Charleston, OR
Role in project: Work to conduct regular and routine communications among members of the project team and the NERRS Science Collaborative, to compile and summarize discussion notes generated during OORAC meetings, serve as co-author of the NSC Biannual reports, and assist with development of presentations, fact sheets, and briefing materials. Mr. Bragg has expertise with condensation of technical research materials into summary sheets, and will provide an interface for the project with the South Slough National Estuarine Research Reserve. John will also provide assistance to the Integration Leader with the SDM process.

A. Progress overview: State the overall goal of your project, and briefly summarize in one or two paragraphs, what you planned to accomplish during this period and your progress on tasks for this reporting period. This overview will be made public for all reports, including confidential submissions.

Project Goal: The overall goal of this project is to investigate the importance of reproductive timing and output, larval supplies, estuarine retention time, settlement, and recruitment as factors that potentially limit recovery of self-sustaining populations of *Ostrea lurida* in Coos Bay and the South Slough estuary. Our specific objectives are to: (A) bring together a diverse group of stakeholders and user-groups to form an Olympia Oyster Recovery Advisory Committee (OORAC); (B) determine the suite of intrinsic ecological, reproductive, and early life-history factors that contribute to the success of Olympia oyster restoration efforts in Coos Bay/South Slough; and (C) integrate the perspectives and collective knowledge from resource agencies, academic investigators, mariculture operators, restoration practitioners, and recreational stakeholders during development of an Olympia Oyster Conservation and Recovery Strategy for Coos Bay.

Accomplishments: Members of the science team met on 25 Jun 2012 at the University of Oregon / Oregon Institute of Marine Biology (OIMB) to discuss the progress and summer

workplans for the three graduate students. The students continued their thesis work that is focused on the reproductive biology and larval ecology of Olympia oysters (*Ostrea lurida*) in the Coos Bay estuary (Oregon). Mark Oates (MSC candidate; Dr. Craig Young thesis advisor) continued his investigation of gametogenesis, brooding, and brood release among populations of *O. lurida* in Coos Bay. Cate Pritchard (MSc candidate; Dr. Alan Shanks thesis advisor) is investigating the physical hydrodynamic characteristics of the greater Coos Bay estuary and how they influence the supplies, dispersion, export, and retention of *O. lurida* larvae. Rose Rimler (MSc candidate; Dr. Richard Emlet thesis advisor) is documenting the seasonal pattern of larval settlement, metamorphosis, survival, and growth at multiple locations throughout the Coos estuary. All three of the OIMB graduate students are supported by the NERRS Science Collaborative.

Over the past eight months (Jan to Aug 2012) Mark Oates has conducted monthly collections of adult Olympia oysters and bimonthly measurements of multiple ambient water quality parameters (*i.e.*, temperature, salinity, chlorophyll) from two intertidal sites within Coos Bay (Haynes Inlet and Coalbank Slough). The oysters are measured, examined in the laboratory to determine and classify their reproductive condition, and dissected for paraffin histology and analysis of the gonadal tissues. Thin sections of the gonadal tissues are examined under a compound microscope, and the Reproductive Condition Index (*i.e.*, stage of gametogenesis) is recorded for each individual oyster. Histological analysis of the oyster gonads is completed (*i.e.*, sex category, maturity stage, oocyte diameter), and the data have been compiled for the period from Jan to Aug 2012. Brooding Olympia oysters were observed in Jul and Aug 2012, and these individuals allow for estimation of the numbers of brooded embryos and larvae per adult oyster (brood sizes). Field collections and characterization of the reproductive stages of the Olympia oyster populations will continue through Dec 2012.

Over the last six months, Rose Rimler and Cate Pritchard worked together to refine the design, deployment, and monitoring for a set of integrated field experiments to assess the supplies and settlement of *Ostrea lurida* larvae at multiple locations within Coos Bay. A series of replicated ceramic settlement plates (attached to PVC pipe) and replicated larval settlement tubes (five per site) were out-planted into the soft sediments in the lower intertidal zone along the edges of the primary tidal channel at five locations: (A) Empire tideflats; (B) Haynes Inlet; (C) downtown Coos Bay; (D) Coalbank Slough; and (E) Catching Slough. Approximately every two weeks, the larval traps and settlement plates were recovered from the field and returned to the laboratory for examination and processing. Both the larval traps and settlement plates were replaced with new collectors at the time of recovery. In the laboratory, the contents of the larval traps and settlement plates are examined under a stereomicroscope, and the numbers of Olympia oyster (*O. lurida*) and Pacific oyster (*Crassostrea gigas*) larvae and spat are sorted, identified, enumerated, and measured. Over the past three months (Jun-Aug 2012), larval and post-larval oysters have been observed in the traps and on the settlement plates on every sampling date. However, the larval and juvenile oysters were not present at every sampling site, and they are clearly more abundant at some sites and less abundant at others. In particular, consistent numbers of *O. lurida* settlers were observed at the Haynes Inlet site, and it was unexpected that a large number of *C. gigas* settlers were also observed in Haynes Inlet in early June 2012 (see Part B Unanticipated Opportunities, below). Very few settlers were observed at the Coalbank Slough site, but large numbers of settlers were observed on the plates deployed along the waterfront of Coos Bay. Rose and Cate will continue to monitor the larval traps and settlement plates every two-weeks through December 2012 to ensure that their acquired datasets span the entire period of pre-settlement, early, peak, and diminished, and post-settlement for *O. lurida* in Coos Bay (Jun-Dec 2012). Rose will initiate a new experiment to examine variability in post-settlement growth rates at the different study sites over the winter months of 2013.

Rose has also maintained a laboratory culture of *Ostrea lurida* larvae and early settlers (obtained from Matt Gray; Oregon State University / Hatfield Marine Science Center) and a culture of recently settled *Crassostrea gigas* spat (obtained from Lili Clausen; Silver Point Oyster Company). These laboratory cultures allow for side-by-side comparison of the appearance and morphology for early settlers of the two species, and help with the identification of the new settlers on the ceramic plates.

In addition to monitoring the larval traps, Cate is also collecting fundamental measurements for several ambient water parameters that may be important to the supplies of Olympia oyster larvae within the estuary. She maintains a series of dataloggers (water level, temperature, salinity) deployed at five strategic points in the estuary to record measurements of water temperature and salinity throughout the seasonal period of brood release, larval dispersion, and settlement. Cate is also collecting new information on the potential role of tidal flushing and tidal amplitudes in the net retention or export of *Ostrea lurida* larvae from their origins in the Coos Bay estuary into the nearshore ocean waters.

Earlier in the project, NSC Principal Investigator Steve Rumrill (South Slough NERR / Oregon Department of Fish and Wildlife) worked with an Oregon Sea Grant Scholar (Joanne Choi; Yale University) to develop, construct, and deploy a series of small-scale, modular, experimental, artificial substrata that were designed to enhance localized recruitment of Olympia oysters. The OLY-ROCS (Olympia Oyster - Restoration of Oysters on Concrete Substrata) were deployed in sets of six replicate units at two locations in Coos Bay (Haynes Inlet and Isthmus Slough; August 2011). In July 2012, Steve conducted a field assessment of the OLY-ROCS and found evidence that larval settlement and successful recruitment had occurred over the summer/fall of 2011 at the Isthmus Slough site, but not at the Haynes Inlet site. This observation of variability in recruitment success on the OLY-ROCS (*post-facto* evidence based on shell size-frequencies), coupled with bi-weekly observations of differential settlement on the ceramic plates (near real-time evidence), indicates that larval settlement has been consistent in the upper mesohaline region of Coos Bay where tidal waters are typically retained within the estuary, but more variable in the mid region at Haynes Inlet where tidal waters are more completely flushed.

B. Working with Intended Users:

- Describe the progress on tasks related to the integration of intended users into the project for this reporting period
- What did you learn? Have there been any unanticipated challenges or opportunities?
- Who has been involved?
- Has interaction with intended users brought about any changes to your methods for integration of intended users, the intended users involved, or your project objectives?
- How do you anticipate working with intended users in the next six months?

Integration of Input from Intended Users: Steve Rumrill met individually and in small groups with several members of the Olympia Oyster Restoration Advisory Committee (OORAC) over the reporting period (Apr-Aug 2012) to discuss the progress made by the graduate students and the implications of their findings toward Olympia oyster restoration and other recovery efforts in Oregon estuaries. OORAC members David Landkammer (Oregon Sea Grant / Aquaculture Extension), Chris Langdon (Oregon State University / Molluscan Broodstock Program), Brett Dumbauld (US Department of Agriculture / Agriculture Research Service), Jim Johnson (OR

Department of Agriculture), and Ken Phippen (NOAA / NMFS) met together with Steve and several members of the commercial shellfish industry (Liu Xin (Oregon Oyster Farms), Mark Weigardt (Whiskey Creek Shellfish Hatchery) and others; 10 Aug 2012; Netarts Bay, OR) to discuss commercial shellfish operations, agency regulatory reviews, the role of commercial hatchery facilities in broodstock recovery and restoration of Olympia oysters, the potential impacts of ocean acidification on native and cultivated shellfish, and other issues. OORAC member Ken Phippen (and his staff of 8-10 NMFS coastal ecologists) met with Steve Rumrill (2 Aug 2012; Newport, OR) for a field trip to examine an eelgrass transplant/mitigation site and to discuss the ecological effects of commercial pacific oyster mariculture operations and the potential ecological effects of meso-scale Olympia oyster restoration work in Oregon estuaries. Steve also conducted several phone calls with OORAC member Dick Vander Schaaf (Coastal Conservation Leader / The Nature Conservancy) to discuss plans and scheduling for the next West Coast Native Oyster Restoration Workshop.

Unanticipated opportunities: The recent observation made by OIMB graduate student Rose Rimler of localized larval settlement by Pacific oysters (*Crassostrea gigas*) at the Haynes Inlet study site is unanticipated and poses several questions about assumptions that underlie the local commercial oyster mariculture industry and retention of oyster larvae in Coos Bay. Her observations confirm earlier suspicions about the likelihood for autochthonous propagation, and they present an opportunity to further investigate the reproductive biology and larval ecology of this important mariculture species in the future.

- Assumption A. Adults of *Crassostrea gigas* generally do not spawn in waters that are below 18^{o}C, and Coos Bay is widely regarded to be too cold for successful reproduction of this species. However, reproduction is known to occur occasionally in the local populations of *C. gigas* because low numbers of “feral adult” *C. gigas* have been observed in rocky rip-rap and on cement pilings at several sites in Coos Bay outside of the commercial oyster mariculture plats. How did the feral adult oysters become established if Coos Bay is generally too cold for successful reproduction? It was long suspected that some of the adult Pacific oysters in the mariculture plats reached maturity, spawned, and that their larvae successfully settled into the rip-rap and on pilings where they survived and grew into adults. These suspicions are largely confirmed by the new observation of localized settlement of *C. gigas* concurrent with settlement of Olympia oyster larvae in Haynes Inlet.

- Assumption B. It has long been assumed that any planktonic veliger larvae produced by Pacific oysters will be flushed out of Coos Bay. Pacific oysters have relatively long-lived planktonic larvae that typically remain swimming in the water column for periods of 20-28 days, almost twice as long as the planktonic period for larvae of *Ostrea lurida*. The new observations of localized larval settlement by Pacific oysters in Haynes Inlet confirm that it is possible for larvae with planktonic periods of 20-28 days to be retained within Coos Bay rather than flushed and exported out to sea. Flushing rates for the Coos Bay estuary are known to vary between the seasons and have been estimated at 10-20 days in winter (wet season) and 20-40 days in the dry summer season (Arneson, 1976; Hyde, 2007). These understandings have important implications for the high likelihood of retention of *O. lurida* larvae in Coos Bay where the shorter-lived planktonic larvae remain swimming for a relatively brief period of 8-14 days.

Changes to methods of integration: During the OORAC meeting (Feb 2012) the project team concluded that it will be more effective to meet with commercial oyster growers one-on-one rather than as a group to gain their input about the new science conducted by the OIMB

graduate students and subsequent development of the conservation plan. We have addressed this change to the method of integration by holding one-on-one discussions with members of the commercial mariculture industry, by meeting with the Executive Director (Margaret Pilaro Barrette) and Projects Manager (Connie Smith) of the Pacific Coast Shellfish Growers Association (8 Aug 2012), and by meeting on multiple occasions with the Oregon Sea Grant Aquaculture Extension Agent (David Landkammer; 6 Apr, 14 Jun, 8 Aug, 10 Aug 2012). Steve Rumrill also met with the Community Affairs Manager for the Oregon International Port of Coos Bay (Elise Hamner; 10 Aug 2012) to discuss the role of the port as an economic development agency and their role in the leasing of submerged and submersible lands for commercial oyster mariculture in Coos Bay. One of the longstanding commercial oyster growers (Qualman Oysters) recently sold the business to a new owner, and it is not yet clear who will take over the local management of the oyster mariculture operations in the South Slough. Information gained from these discussions and meetings is shared with members of the project team and scientists during graduate thesis advisory committee meetings (*i.e.*, 25 June 2012) and through direct phone calls and email correspondence.

During the next six months: During the next six months we will maintain periodic contact with intended users and stakeholders to: (1) provide updates on the new scientific assessments of reproduction and larval ecology of Olympia oysters in Coos Bay; (2) work to better integrate the three components of the reproductive biology (Module 1 / reproduction and brooding; Module 2 / larval supplies and dispersal; Module 3 / larval settlement) into the framework for the local Olympia Oyster Conservation and Recovery Plan; (3) continue to use the feedback, input, and other comments provided by OORAC to further refine how the data sets and output generated by the graduate students will contribute to the local conservation plan for Olympia oysters in Coos Bay; (4) clarify and better define the role of state and county-level permitting in the design and implementation of future restoration projects with Olympia oysters along the shoreline of Coos Bay; (5) finalize a new NSC fact-sheet to clarify and summarize the state, federal, and regional agency jurisdiction over management of commercial oyster cultivation activities in Coos Bay; (6) schedule the next OORAC meeting; and (7) invite their participation in the next West Coast Native Oyster Restoration Workshop in Portland, OR (winter 2012-13).

C. Progress on project objectives for this reporting period:

- Describe progress on tasks related to project objectives for this reporting period.
- What data did you collect?
- Has your progress in this period brought about any changes to your methods, the integration of intended users, or the project objectives?
- Have there been any unanticipated challenges, opportunities, or lessons learned?
- What are your plans for meeting project objectives for the next six months?

Progress and Data Collection: The three graduate students from the Oregon Institute of Marine Biology (Mark Oates, Cate Pritchard, Rose Rimler) have continued their thesis work on the reproductive biology and larval ecology of Olympia oysters in the Coos Bay estuary. Input received from the OORAC was incorporated earlier into the objectives and design for the new science activities conducted by the students. Several different types of data were collected by members of the science team over the spring and summer months. Mark Oates (Module 1/ reproduction) collected adult oysters, conducted dissections and prepared histological slides, and analyzed the gonadal tissues to characterize seasonal changes in the different stages of oogenesis, spermatogenesis, gender switching, and brooding for two local populations of Olympia oysters. Cate Pritchard (Module 2 / larval supplies and dispersal) continued to

generate new data to describe seasonal variability in ambient water parameters, and to deploy and recover a series of larval traps to characterize the abundance, supplies, and dispersal of Olympia oyster larvae at strategic locations in Coos Bay. Rose Rimler continued to conduct monthly assessments of the settlement, survival, and growth of Olympia oysters that recruit onto a series of paired ceramic plates deployed at five sites throughout the Coos bay estuary. In addition the graduate students continues to maintain a series of automated dataloggers to record ambient water parameters (i.e., temperature, salinity, water level) at strategic points in Coos Bay, and the South Slough NERR continued to collect time-series measurements of estuarine water quality parameters (estuarine water temp, sal, cond, pH, DO, Chl-a, turb) at several locations along the estuarine gradient of the South Slough.

Changes in methods and integration of intended users: LNG Issue / Background and Recent Action. Stakeholder concerns were raised in 2010-11 about the potential impacts of dredging (associated with excavation and placement of a Liquefied Natural Gas pipeline), turbidity, and sedimentation on survival of populations of native Olympia oysters. The state of Oregon Land Use Board of Appeals (LUBA; March 2011) instructed Coos County to more fully consider any harm that may come to native oysters by excavation of a pipeline trench through Haynes Inlet. In response to this concern, members of the project team and OORAC worked together with outside consultants and external advisors in the summer of 2011 to develop a population survey and mitigation plan to help offset any damages to intertidal and subtidal populations of Olympia oysters in Haynes Inlet. The Coos County Hearings Officer (Andrew Stamp, P.C.; Portland, OR) made his final recommendations to the Coos County Commissioners (March 2012) to indicate that any risk to the populations of Olympia oysters would be slight. In response to this recommendation, there is no longer any need for results L:D-50 bioassay experiment to assess the tolerance and susceptibility of Olympia oyster larvae, post-larvae, and juveniles to exposure to different sediment loads and sedimentation treatments.

Unanticipated challenge: The communities of Coos Bay, North Bend, and Charleston continue to be actively engaged in public debate regarding the scoping and feasibility studies for construction of a new liquefied natural gas (LNG) terminal located along the shoreline of Coos Bay at Jordan Cove. It is likely that members of the science team and OORAC may be asked to provide opinions and/or testimony on this issue as the local LNG planning process continues.

Plan for the next Six Months: During the next six months we will: (1) maintain periodic contact with intended users and stakeholders to provide updates on the new scientific assessments of reproduction and larval ecology of Olympia oysters in Coos Bay; (2) work to better integrate the three components of the reproductive biology (Module 1 / reproduction and brooding; Module 2 / larval supplies and dispersal; Module 3 / larval settlement) into the framework for the local Olympia Oyster Conservation and Recovery Plan; (3) continue to use the feedback, input, and other comments provided by OORAC to further refine how the data sets and output generated by the graduate students will contribute to the local conservation plan for Olympia oysters in Coos Bay; (4) clarify and better define the role of state and county-level permitting in the design and implementation of future restoration projects with Olympia oysters along the shoreline of Coos Bay; (5) finalize a new NSC fact-sheet to clarify and summarize the state, federal, and regional agency jurisdiction over management of commercial oyster cultivation activities in Coos Bay; (6) schedule the next OORAC meeting; (7) hold a post-summer science team meeting to discuss and evaluate progress made by the graduate students; and (8) co-host the next West Coast Native Oyster Restoration Workshop in Portland, OR (winter 2012-

13) that will include a special pre-workshop meeting and exchange between the scientists, students, and staff affiliated with the SSNERR, ESNERR, and SFBNERR who are actively engaged in NERRS Science Collaborative projects that focus on Olympia oysters.

D. Benefit to NERRS and NOAA: List any project-related products, accomplishments, or discoveries that may be of interest to scientists or managers working on similar issues, your peers in the NERRS, or to NOAA. These may include, but are not limited to, workshops, trainings, or webinars; expert speakers; new publications; and new partnerships or key findings related to collaboration or applied science.

- Members of the NSC science team delivered a series of presentations during the 104th National Shellfisheries Association Conference; 26-30 Mar 2012 / Seattle, WA:
  - S. Rumrill and S. Groth / Population recovery, habitat enhancement, and reproductive ecology of Olympia oysters (*Ostrea lurida*) in Coos Bay, OR
  - M. Oates and C. Young / Preliminary observations of gonad structure and gametogenic timing in a recovering population of *Ostrea lurida*

- In addition, two scientists with close associations to the NSC also delivered presentations during the NSA Conference in Seattle:
  - L. Peterio-Garcia, A. Shanks, and S. Rumrill / Seasonal abundance and tidal-timed migration of Olympia oyster larvae in Coos Bay, OR
  - K. Sawyer / Settlement preference and the timing of settlement of the Olympia oyster (*Ostrea lurida*) in Coos Bay, OR

- Project PI S. Rumrill described the objectives and early results from the NSC during an extended interview on a local radio station (Oregon Outdoors / 23 Aug 2012)

E. Describe any activities, products, accomplishments, or obstacles not addressed in other sections of this report that you feel are important for the Science Collaborative to know.

- The project PI (Steve Rumrill) and several members of the OORAC (Laura Hoberecht, David Landkammer, Chris Langdon, Brett Dumbauld) are currently working with members from private industry (*i.e.*, Pacific Coast Shellfish Growers Association) on early development of the Oregon Shellfish Initiative. This cooperative and collaborative initiative is designed to help meet many of the goals of the National Shellfish Initiative, and will likely include a component that is focused on enhancement, restoration, and recovery of Olympia oyster populations in Oregon estuaries.

- Staff members from the South Slough NERR moved about 400 bags of juvenile and adult Olympia oysters from a temporary grow-out site in the South Slough (Younker Point) to their final field site located at Long Island Point. The bags of aged cultch (living Olympia oysters attached to non-living Pacific oyster shells) were transported to Long Island Point, cut open, and the Olympia oysters and shell were distributed freely in the intertidal zone in an effort to re-establish a viable population within the South Slough estuary.

Appendix. Photographs of field work, histological section, collection apparatus, early juvenile, and adult Olympia oysters

Figure 1. Mark Oates (OIMB graduate student) collects a representative sample of adult Olympia oysters along a transect line at the Coalbank Slough study site (June 2012).

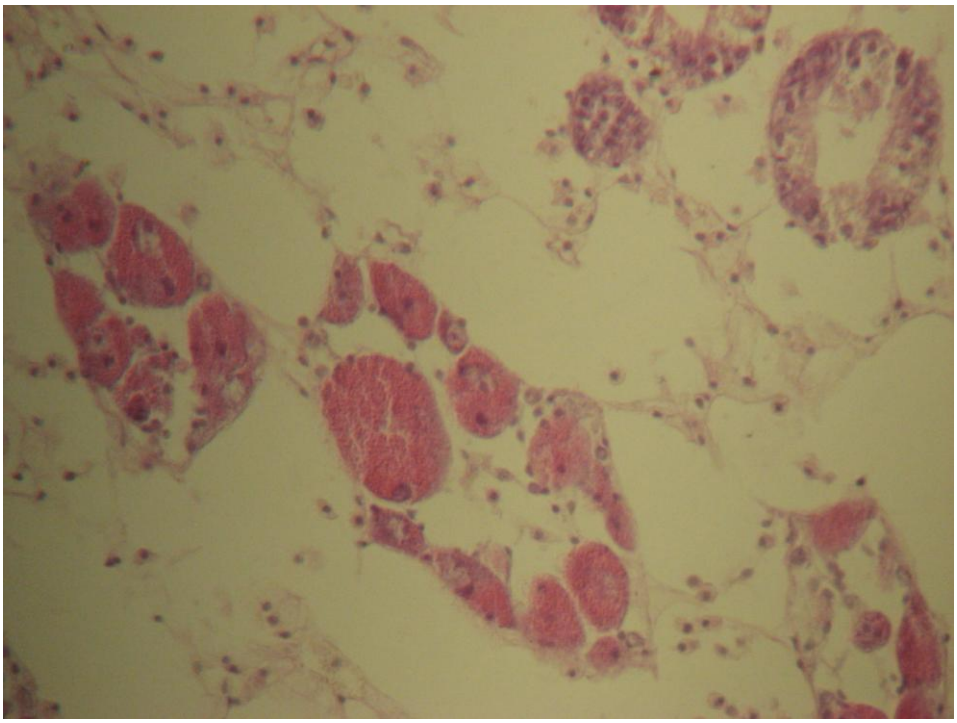

Figure 2. Histological section through the ovary of *Ostrea lurida* (Feb 2012) that illustrates an early stage of gametogenesis when the largest oocytes are 30-40 um in diameter.

Figure 3. Array of replicated larval traps (vertical tubes) and paired ceramic settlement plates (horizontal squares) deployed in Coos Bay by OIMB graduate students Cate Pritchard and Rose Rimler to assess seasonal changes in larval supplies, settlement, survival, and growth

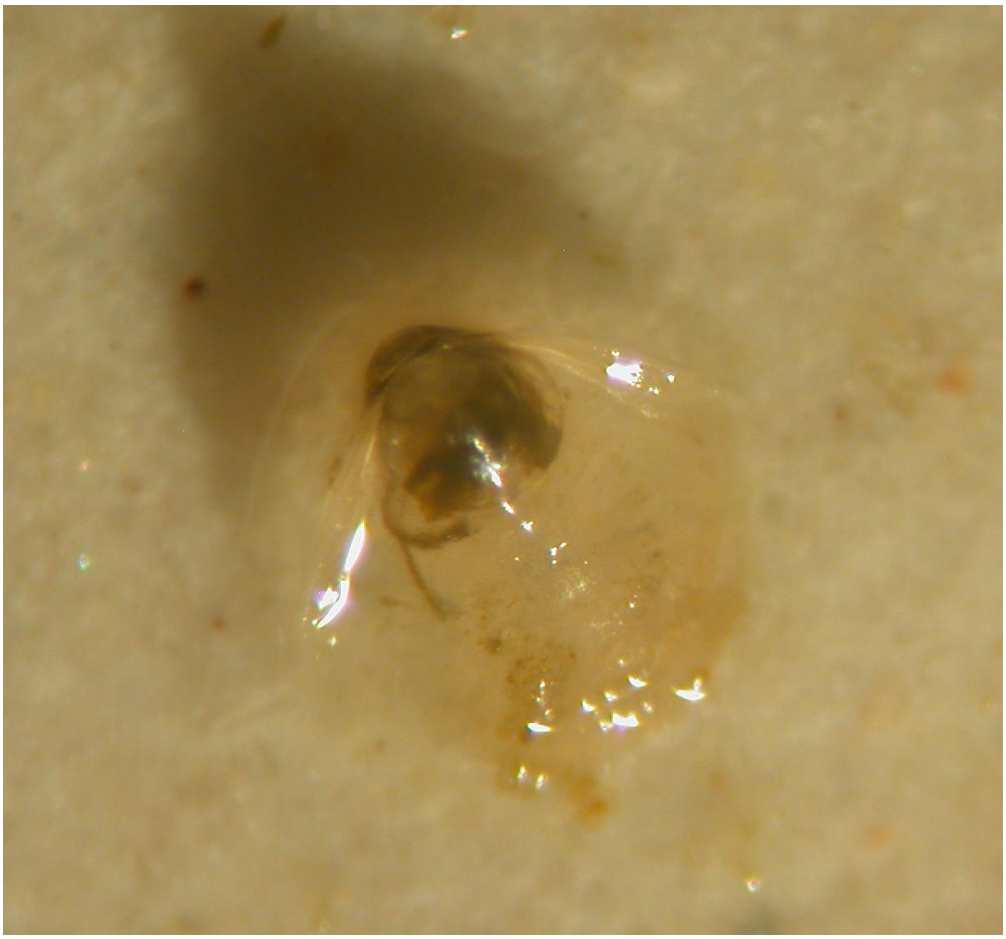

Figure 4. Early juvenile Olympia oyster that has recently settled and completed metamorphosis on an experimental ceramic plate.

Figure 5. Living adult and juvenile Olympia oysters attached to non-living Pacific oyster shells during deployment of within an experimental population enhancement site at Long Island Point, South Slough estuary (OR, Jul 2012).